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The Respiratory Health of School Children in Smelter Communities

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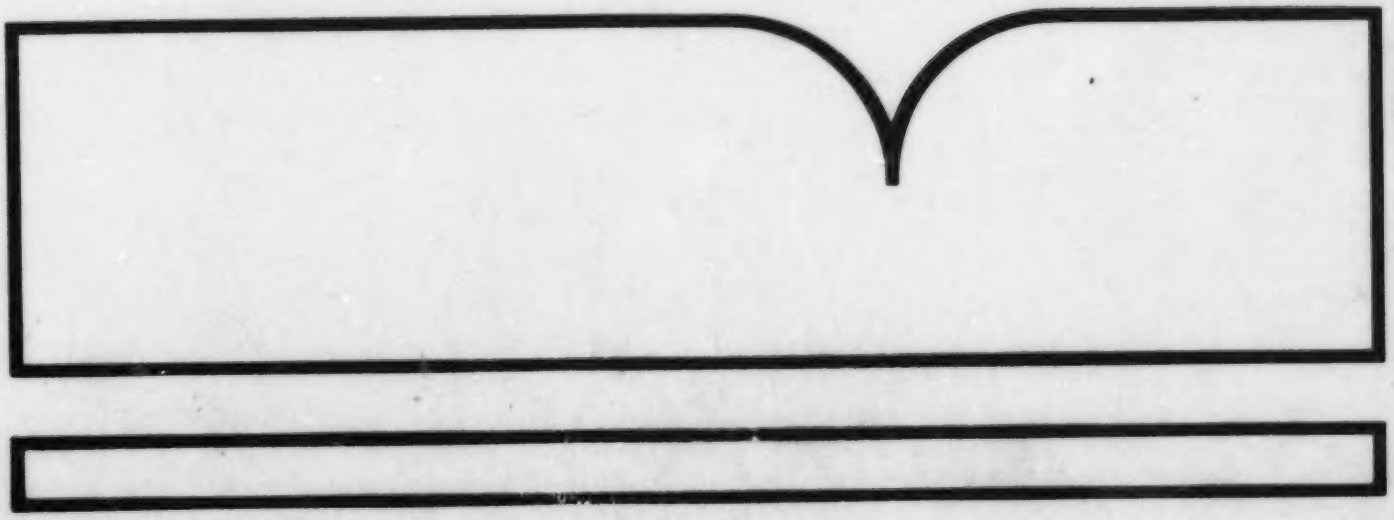

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16. ABSTRACT

This study compares the pulmonary function and prevalence of respiratory symptoms and disorders among school children living in smelter towns and other communities of Arizona. The rate of asthma was found to be significantly higher in whites than Mexican-Americans, although differences in related problems, such as wheezing, were not significant. When the subjects were grouped by area of residence, the children living in areas with relatively high particulate levels had significantly lower pulmonary function than children living in areas with low particulate levels. No relation between symptoms or pulmonary function and sulfur dioxide levels observed.

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The Respiratory Health of School Children in Smelter Communities

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This study compares the pulmonary function and prevalence of respiratory symptoms and disorders among school children living in smelter towns and other communities of Arizona. The rate of asthma was found to be significantly higher in whites than Mexican-Americans, although differences in related problems, such as wheezing, were not significant. When the subjects were grouped by area of residence, the children living in areas with relatively high particulate levels had significantly lower pulmonary function than children living in areas with low particulate levels. No relation between symptoms or pulmonary function and sulfur dioxide levels was observed.

Key words: children, health, particulate, smelters, spirometry

INTRODUCTION

The ambient levels of total suspended particulates (TSP) and sulfur dioxide (SO_2) vary widely in the nonurban areas of Arizona [Arizona Department of Health Sciences, 1978]. This variation is due to differences in the amount of fugitive dust present in different locales and because of the presence of copper smelters with their emissions in certain communities.

These conditions have provided the opportunity to study the health of children exposed to different levels of these pollutants. Some of the children enrolled in our study live in areas where relatively high levels of TSP or SO_2 intermittently occur [Arizona Department of Health Sciences, 1978]. To test the hypothesis that there is a relationship between ambient levels of TSP or SO_2 and the respiratory morbidity and lung function of children, we compared children living in areas where relatively high levels of TSP or SO_2 occur and children living in areas where they are exposed to lower levels of these pollutants.

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METHODS AND MATERIALS

The parents of all children enrolled in the third through the fifth grades of elementary schools in Morenci, Kingman, Mammoth, Stargo, and San Manuel, Arizona, were contacted and asked to allow their children to participate in our study. The study consisted of a questionnaire to be completed by the parents and spirometry to be done by the children. Of 999 children who were eligible, signed consents and spirometry results were obtained on 784, a participation rate of 78.5%. Questionnaires were completed by the parents of 794 of the children, and 740 of those children also did the lung function tests. Four of the enrolled children were not white or Mexican-American; their pulmonary function results are not included here.

The questionnaire contained questions selected from the standard questionnaire of the Tucson Epidemiologic Study of Obstructive Lung Disease [Lebowitz et al, 1975]. Spirometry was done with a CPI dry-seal rolling spirometer. Each child was instructed on how to perform the test and was then asked to complete at least three maximum expiratory maneuvers. Further efforts were requested of subjects who did not produce a second-best forced vital capacity (FVC) within 5% of their best FVC.

The single-best FEV_1 and FVC were used in the analyses. The $Vmax_{50}$ and $Vmax_{75}$ of the curves with the maximum sum of FEV_1 plus FVC were the flow values used. These values, corrected for body temperature, pressure, saturation (BTPS), are expressed in terms of the percent predicted. Predicted values were based on the subject's height cubed, using prediction formulas derived from the asymptomatic, nondiseased subjects of the population.

The areas in which our subjects live have different ambient levels of TSP and SO_2, as shown in Table I. Intermittent monitoring of these communities for photochemical oxidants and nitrogen dioxide has revealed only background levels of these compounds.

The towns of Morenci and San Manuel are southern Arizona smelter towns with about 7,000 residents each. Two of the other areas, Stargo and Mammoth, are located one mile and six miles, respectively, from smelters. Prevailing winds explain the levels of SO_2 in these areas. Kingman is a community in northwestern Arizona of 7,000 residents without a major industrial emissions source.

RESULTS

The point prevalence of positive answers to questions about asthma (requiring visits to a physician), wheezing, cough, and sputum production are shown in Table II.

The rate for asthma is significantly higher among the white children than for the Mexican-American children ($p < 0.05$). No other significant differences were found between whites and Mexican-Americans or between boys and girls.

Five social classes were established for the sample, based on parents' education. No significant differences in the rates of asthma or of respiratory symptoms occurred among these classes.

To ensure further that the ethnic difference in asthma rate was not explained by differences in socioeconomic status, a class-adjusted rate for these indicators of respiratory morbidity was calculated. The significant difference in asthma rates between the white children and the Mexican-American children persisted.

Grouping the subjects by where they lived revealed no significant differences in the point prevalence of asthma or respiratory symptoms. When the subjects were further

TABLE I. Levels of Total Suspended Particulates and SO_2 in Study Areas

	TSP as $\mu g/m^3$		SO_2 as $\mu g/m^3$	
	Annual average[a]	Second highest 24-hour level per year[b]	Annual average	Second highest three-hour level per year[c]
Morenci	72	550[d]	16	1,062
Stargo	37	100	86[d]	3,658[d]
Kingman	54	125	4	—
Mammoth	76[d]	119	8	703
San Manuel	45	84	51	1,712[d]

[a]Annual average is an average of the annual averages from 1976 to 1978.
[b]Second highest 24-hour level is an average of the second highest 24-hour levels of each year from 1976 to 1978.
[c]Second highest three-hour level is an average of the second highest three-hour levels of each year from 1976 to 1978.
[d]Exceeds U.S. air quality standards.

TABLE II. The Point Prevalence of Asthma* and Selected Respiratory Symptoms in School Children

		Prevalence rate per 100			
	Number	Asthma	Wheeze	Cough	Sputum
Entire sample	794	4.5	22.8	21.5	9.5
Whites	468	5.9[a]	24.8	20.9	9.5
Mexican-Americans	326	2.5	19.9	22.4	9.7
Males	391	6.0	22.0	24.0	10.3
Whites	231	7.5	21.0	23.4	10.4
Mexican-Americans	160	3.9	23.5	25.0	10.0
Females	403	3.1	23.7	19.1	8.8
Whites	237	4.3	28.6	18.6	8.5
Mexican-Americans	166	1.3	16.5	19.9	9.3

*Requiring visits to a physician.
[a]Rate is significantly higher in whites than in Mexican-Americans ($p < 0.05$).

divided into those living in areas with high levels of TSP (Morenci and Mammoth) and with low levels of TSP (Stargo, Kingman, and San Manuel), the whites living in the high TSP areas had cough and sputum rates of 24.2% and 13.0%, respectively (Table III). The rates of these symptoms in whites living in low TSP areas were 19.0% and 7.3%. The Mexican-American children had higher rates of wheezing and cough among those living in the low TSP areas. These differences were not statistically significant.

The results of the pulmonary function testing are reported as the percent predicted, based on the prediction formulas developed for each sex and ethnic group. When the subjects were grouped by social class, no significant differences in pulmonary function were seen among the five classes. When the subjects were grouped by area of residence, among the white children only the percent predicted FVC varied significantly. Among the Mexican-American children, the percent predicted FEV_1, FVC, and $Vmax_{50}$ varied significantly among the groups.

As Table IV shows, when the subjects were grouped into those living in areas with high levels of TSP (Morenci and Mammoth) and low levels of TSP (Stargo, Kingman, and San Manuel), the FEV_1 and FVC are significantly lower for all subjects living in

TABLE III. Point Prevalence of Asthma and Selected Respiratory Symptoms in Children Grouped Into High and Low TSP Areas of Residence

	Number	Prevalence rate per 100			
		Asthma	Wheeze	Cough	Sputum
Whites					
Subjects in high TSP areas	178	6.9	23.8	24.2	13.0
Subjects in low TSP areas	290	5.3	25.4	19.0	7.3
Mexican-Americans					
Subjects in high TSP areas	225	2.7	18.0	21.3	10.4
Subjects in low TSP areas	101	2.1	24.5	24.8	8.1

TABLE IV. Pulmonary Function Test for Children Grouped Into High and Low Levels of TSP by Residence

	Number	Percent predicted ± S.D.			
		FEV_1	FVC	$\dot{V}max_{50}$	$\dot{V}max_{75}$
Whites					
Subjects in high TSP areas	159	96.4 ± 15.2[a]	96.2 ± 15.7[a]	98.6 ± 22.7	97.6 ± 24.9
Subjects in low TSP areas	293	100.0 ± 15.5	100.0 ± 16.3	99.0 ± 21.3	100.2 ± 26.2
Mexican-Americans					
Subjects in high TSP areas	215	97.0 ± 13.7[b]	96.7 ± 14.0[b]	96.8 ± 20.8	97.8 ± 25.2
Subjects in low TSP areas	113	105.4 ± 13.6	105.9 ± 14.7	105.0 ± 23.7	103.1 ± 26.4

[a]Significantly lower than for white subjects in low TSP areas ($p < 0.05$).
[b]Significantly lower than in Mexican-American subjects in low TSP areas ($p < 0.01$).

areas of high TSP. In addition, the flow parameter $\dot{V}max_{50}$ is significantly lower for the Mexican-American children living in the high TSP areas.

DISCUSSION

Although it is clear that the presence of much higher levels of TSP than were observed in our study is associated with an increased frequency of respiratory morbidity and pulmonary function abnormalities in children [Lunn et al, 1967], the threshold at which these substances produce adverse effects in the general population or sensitive subgroups of the population has not been determined. In our subjects, some of whom have been exposed intermittently to high levels of TSP or SO_2, lower levels of pulmonary function were seen in subjects exposed to high levels of TSP. No significant differences were seen, however, in the rates of asthma or certain other respiratory symptoms.

The white children did have a significantly higher rate of asthma than did the Mexican-American children. Our definition of this entity, however, required an "asthmatic" subject to have been seen by a physician for this problem. The difference seen may reflect a different rate of subject-physician encounters in the two ethnic groups. Support for this speculation comes from the very similar rates of wheezing and other symptoms that are seen in the two groups.

Although our results are consistent with the hypothesis that there is a relationship between TSP levels and the pulmonary function of children exposed to various levels of TSP, the differences, by themselves, are not adverse health effects. The symptom and disease rates are about the same in all areas, and they are comparable to those seen in other studies in this region [Arizona Department of Health Sciences, 1978].

We chose to study children in order to decrease the number of independent variables present. We did examine the symptoms and pulmonary function of the children while controlling for ethnic background, sex, and socioeconomic status of their parents, as mentioned. In addition, we grouped the children according to parental smoking habits. We found higher rates of symptoms among the children of smoking parents, but no differences in pulmonary function among the groups. These results may simply reflect an increased reporting of symptoms by smoking parents who tend to have more symptoms than nonsmoking parents [Harlap and Davies, 1974; Colley et al, 1974; Lebowitz et al, 1976].

We realize that our subjects, so many of whom live in areas where most heads of households work in some aspect of copper production, are probably not representative of children in the general population. It is possible, for example, that families who have members who develop respiratory problems tend to leave smelter communities. Thus, in these areas we might be sampling from a population with abnormally high pulmonary function.

It is important to consider that such a selective bias may be at work because it could serve to explain some of our findings. Most of the subjects, essentially all of the Mexican-American children, live in areas of either intermittently high levels of TSP or intermittently high levels of SO_2. Although it is true that the children living in areas of high TSP, Morenci and Mammoth, have significantly lower pulmonary function results than the entire sample, it could also be stated that the children living in Stargo and San Manuel, areas of high levels of SO_2, have significantly higher pulmonary function results than the values for the entire sample. Because Mexican-American children live almost exclusively in one or the other of these areas, it is not possible to refute the argument that the association seen between TSP and pulmonary function in this ethnic group is an artifact. For whites, however, because the subjects in Kingman have lung function values about the same as those in the high SO_2 areas, but significantly higher FEV_1 and FVC than those in the high TSP areas, it appears that the association between TSP levels and pulmonary function is real.

We have employed the maximum expiratory flow-volume curve in our study to allow us to measure flow at the middle and low lung volumes in addition to measuring the FEV_1 and FVC. After the initial approximately one-third of the vital capacity has been expired, flow becomes effort independent, and parameters such as $Vmax_{50}$ and $Vmax_{75}$ are determined by lung elastic recoil and by the resistance of the small airways. Because morphologic studies have demonstrated that persons who are thought to be at an increased risk for developing chronic airways disease, such as cigarette smokers, frequently have inflammation and decreased caliber of their small airways, investigators have theorized that persons with abnormal flows at the middle and low lung volumes, but with normal FEV_1, may have early manifestations of chronic airways disease. This hypothesis, that an abnormal $Vmax_{50}$ or $Vmax_{75}$ is a precursor of clinical airways disease, has not yet been proved.

We have found the FEV_1 and FVC to be consistently lower in subjects living in areas of high TSP. If small airways abnormalities are the earliest changes that occur in

persons destined to develop chronic disease, an unproved theory, then one would expect the subjects living in areas of high TSP to have lower $Vmax_{50}$ and $Vmax_{75}$ than the other subjects if the exposure to TSP is of future importance. However, there is little evidence available to support such a speculation. On the contrary, Knudson and his associates found that, in subjects under age 35 participating in a community study, the FEV_1 was more frequently abnormal than the $Vmax_{50}$ or $Vmax_{75}$ among persons who were symptomatic or cigarette smokers [1976].

Our results cannot be interpreted to mean that the children living in areas of high TSP are at increased risk of subsequent development of chronic disease. That possibility does exist, however, and only longitudinal study of these subjects can determine the importance of these findings.

It is important to note that the TSP present in Morenci and Mammoth may be very different in size, acidity, and chemical composition from TSP in other regions. These areas are close to copper smelters, and interactions between fugitive dust and stack emissions may be producing TSP that are unique to these areas. Studies are in progress to characterize further the TSP found in all the areas under study.

In summary, we have found significant differences in the pulmonary function, but not in the rates of asthma or respiratory symptoms, in children living in different nonurban areas of Arizona. Lower pulmonary function was found in areas with high levels of TSP; no such association was found with SO_2. Longitudinal studies will be necessary to determine the importance of these findings. Because of the proximity of the areas with high levels of TSP to copper smelters, further characterization of these compounds is being done to compare this form of total suspended particulates to that which occurs in other regions. The further characterization of TSP may help explain the relationship seen between the level of these compounds and the pulmonary function test results of our subjects.

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